Maryland Lower Western Shore

Final Version for 1985-2002 Data

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Maryland Lower Western Shore Basin Characteristics

Maryland's Lower Western Shore drains 305 square miles of land in Anne Arundel and Calvert counties (Figure LWS1). The main rivers in the basin are the Magothy, Severn, South, Rhode, and West Rivers. The entire basin lies in the Coastal Plain Province. In many areas near tidal waters, the hill-terrain forms cliffs along the shoreline. Because of low elevations in the basin, surface waters generally flow sluggishly in winding courses, often through wetlands before reaching the Bay.

The census population for 2000 for the basin was 278,000 people. Major population centers in basin include Annapolis, Severna Park, and Arnold.

The Lower Western Shore of the Chesapeake Bay in Maryland is a largely forested and urban area. The dominant land use in the basin is classified as forested (46 percent). Urban areas comprise the second largest land use at 40 percent. About 14 percent of the basin is devoted to agricultural use. Barren land accounts for less than 1 percent of the basin.

Urban areas comprise the second largest land use at 40 percent. The majority of this urban development is classified as low intensity (86 percent). Six percent is high intensity, and eight percent is considered commercial development.

Nearly 82 percent of the housing in the basin is urban, with most of the remaining housing in rural areas. In spite of this preponderance of urban housing, a smaller percentage of homes in the basin rely on municipal water and sewage systems. Only 62 percent of the basin's housing relies on a municipal sewage system and 59 percent of the housing uses a public water source. Consequently, point sources are not the dominant contributor of nutrient loadings in Maryland's Lower Western Shore. There are eight municipal sewage facilities in the basin, with Biological Nutrient Removal implemented at four of them. BNR implementation is planned for another facility by 2005. Appendix A contains graphs of average monthly nutrient loads from the basin's major wastewater treatment facilities.

About 14 percent of Maryland's Lower Western Shore is agricultural land. A series of Best Management Practices have been planned to help reduce non point source loads. BMP implementation for structural shore erosion control, marine pumpout installation, septic connections and denitrification, and nutrient management plans are all making good progress toward Tributary Strategy goals. For other issues, such as stormwater and urban runoff management, forest conservation, forested and grassed buffers, and stream protection, progress has been slower and in some cases, non-existent.

As of 2002, the most significant contributors of nitrogen to Maryland's Lower Western Shore were urban and point sources (40 percent each). Agriculture and mixed open lands each only contributed 7 percent of the nitrogen load. For phosphorus, the largest contributor was urban sources (63 percent), followed by point sources (20 percent). Agricultural and mixed open lands each contributed approximately 7 percent.

Figure LWS1 – Map of the Lower Western Shore Basin

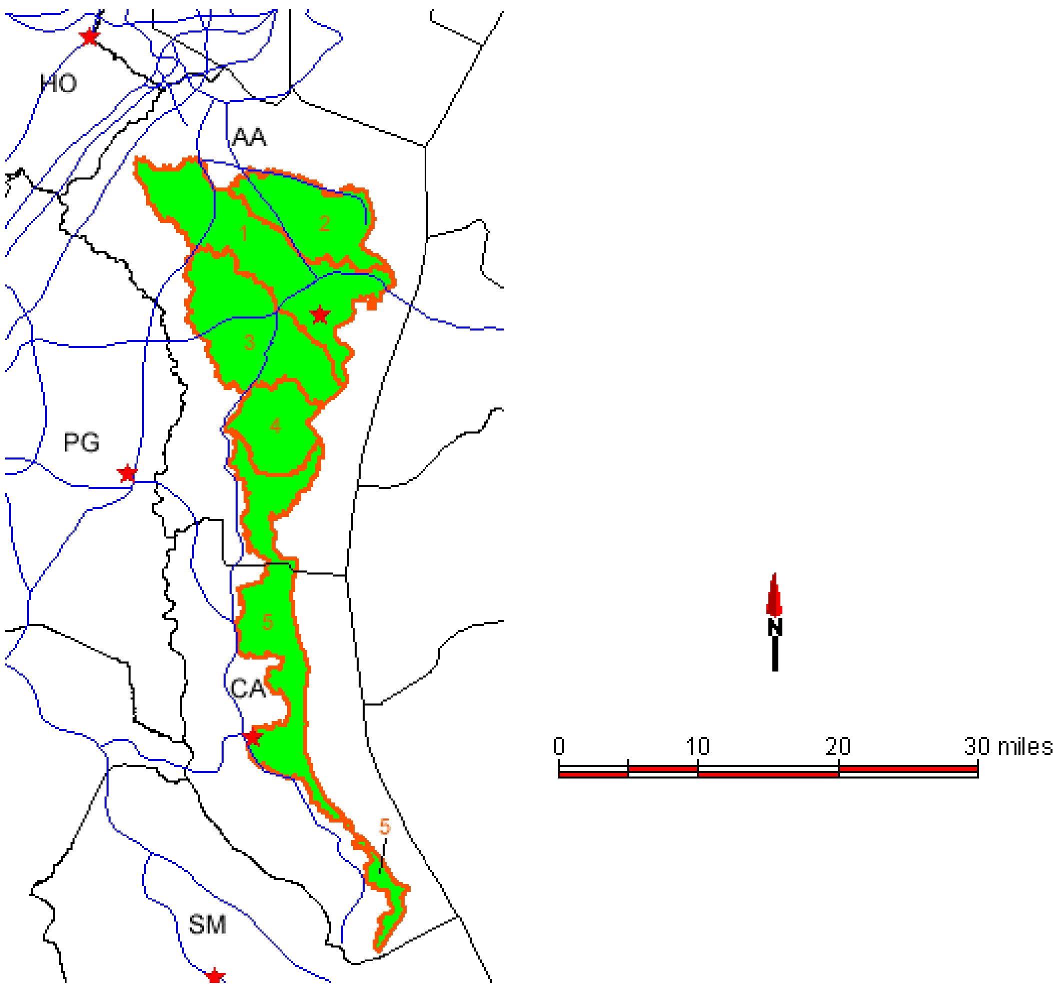


Figure LWS2 – 2000 Land Use in the Lower Western Shore Basin

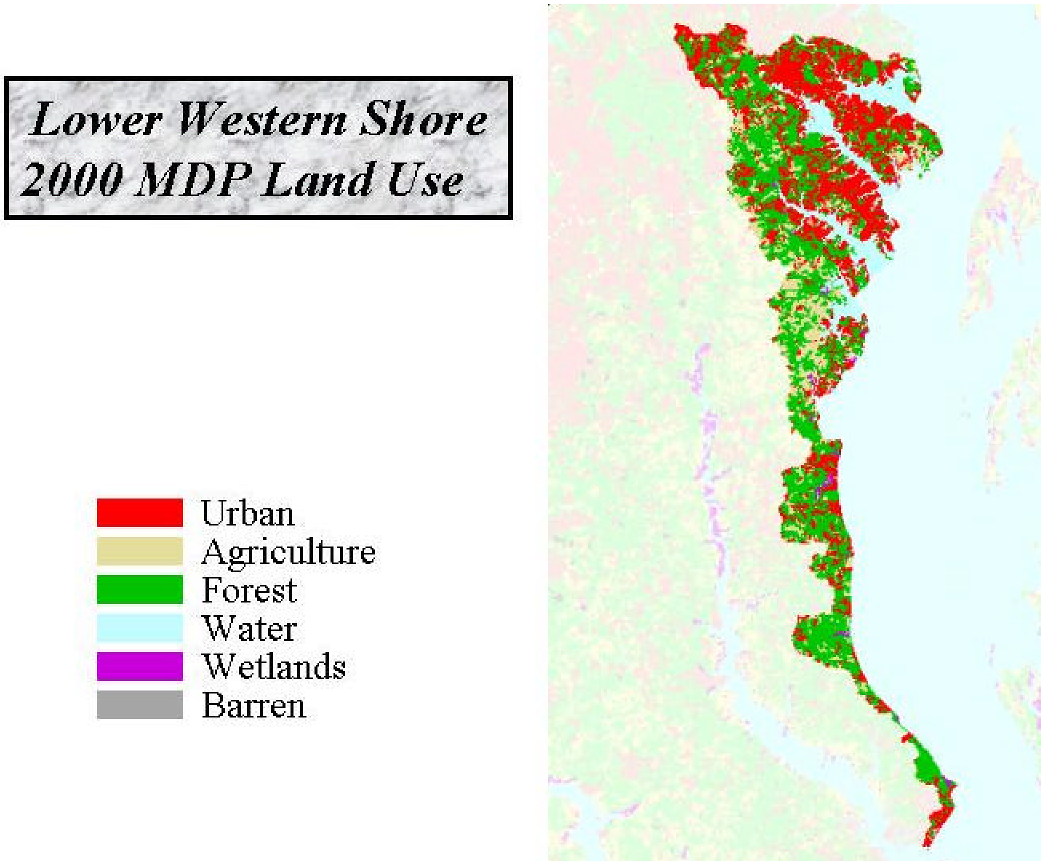


Figure LWS3 – Wastewater Treatment Plants in the Lower Western Shore Basin

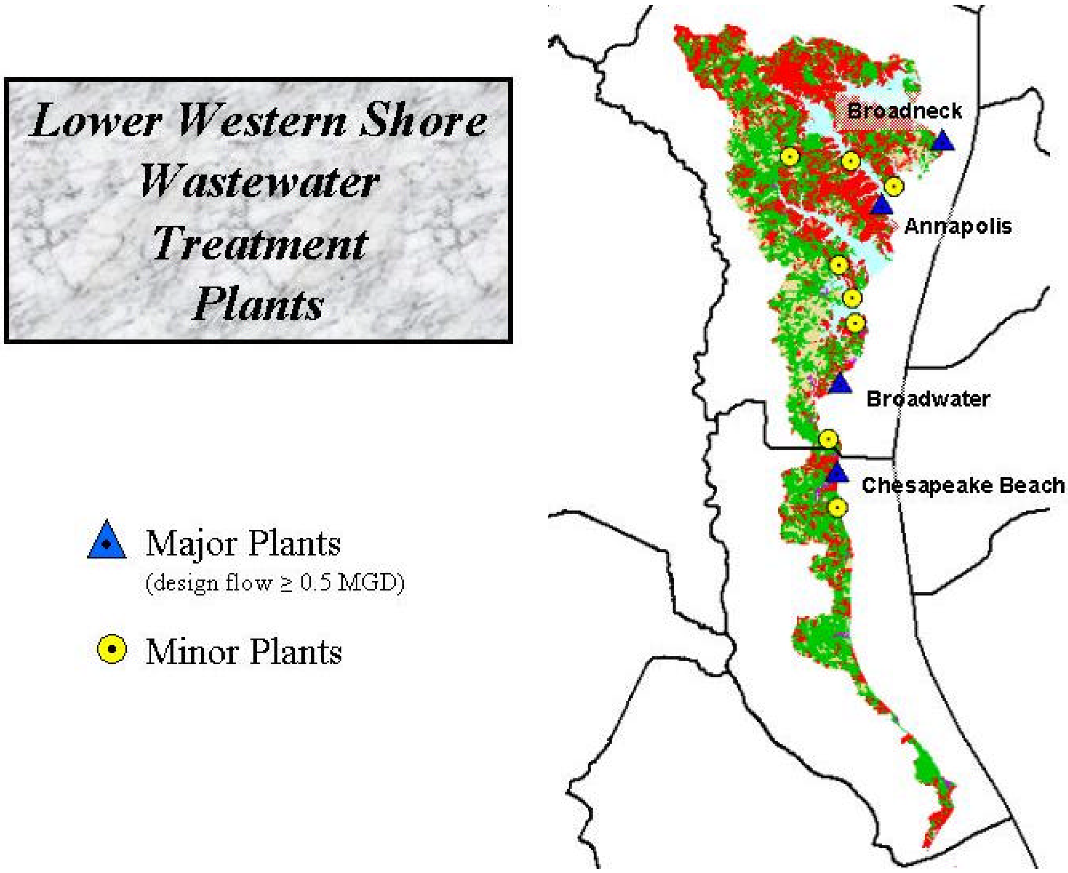


Figure LWS4 – 1985 and 2002 Nitrogen Contribution to the Lower Western Shore by Source.

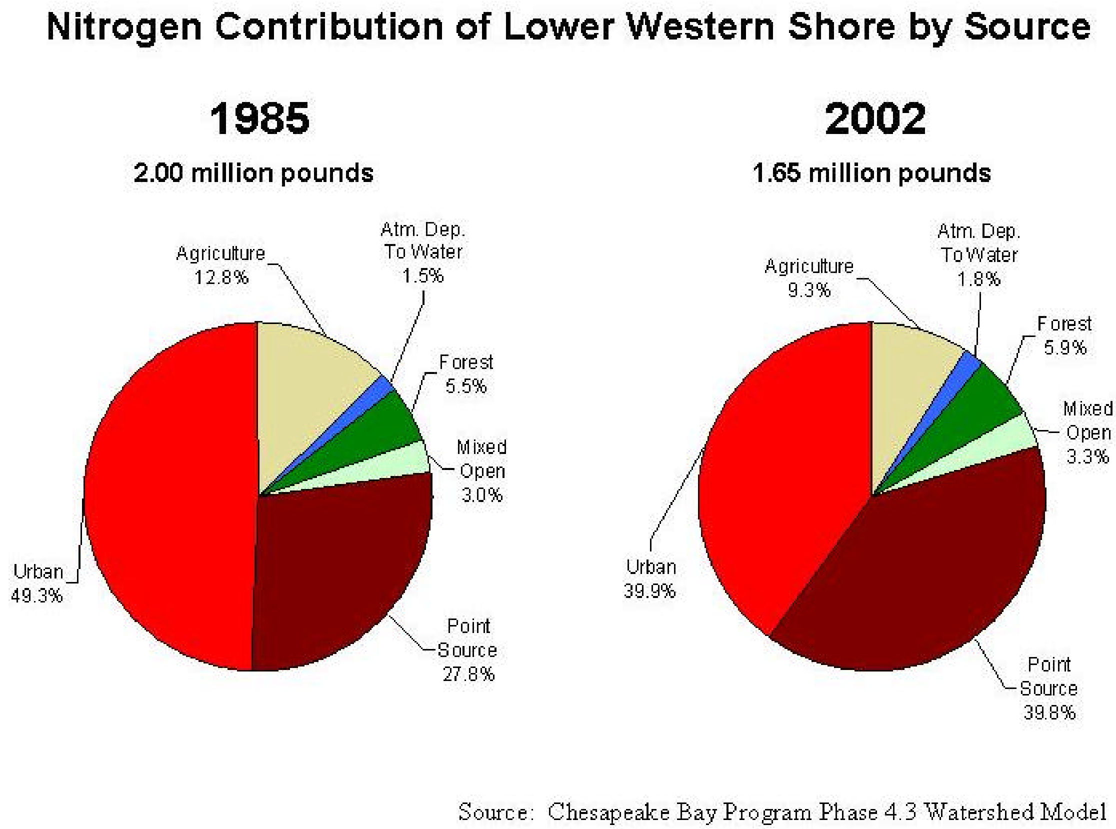
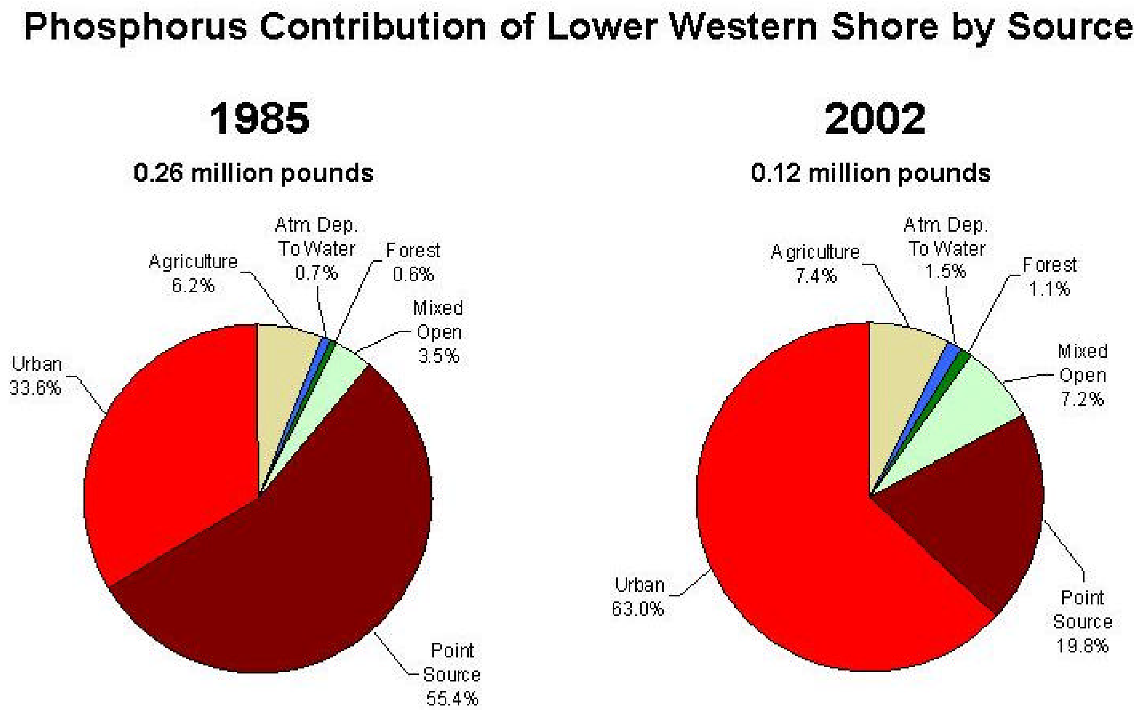


Figure LWS5 – 1985 and 2002 Phosphorus Contribution to the Lower Western Shore by Source.



Source: Chesapeake Bay Program Phase 4.3 Watershed Model

Figure LWS6 – 1985 and 2002 Sediment Contribution to the Lower Western Shore by Source.

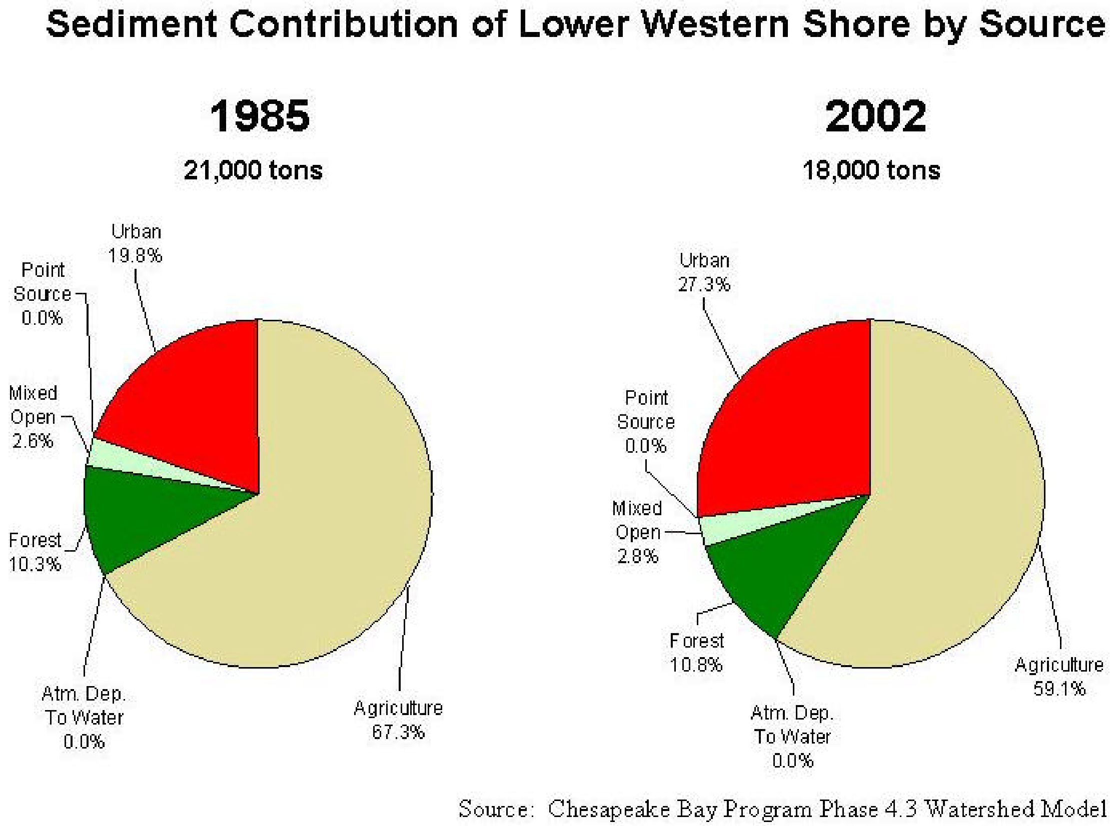


Figure LWS7 – Total Nitrogen in the Lower Western Shore.

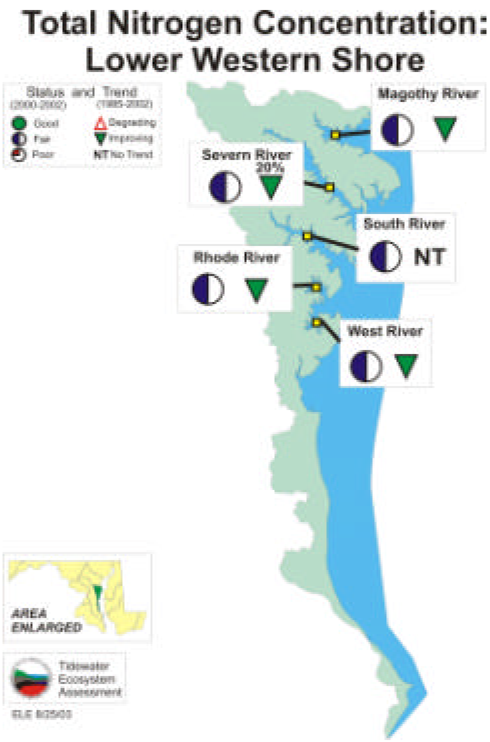


Figure LWS8 – Total Phosphorus in the Lower Western Shore.

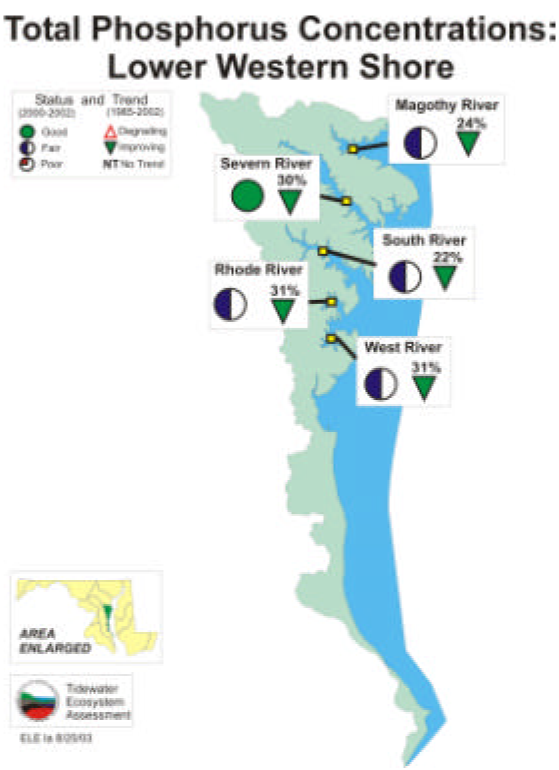


Figure LWS9 – Algal Abundance in the Lower Western Shore.

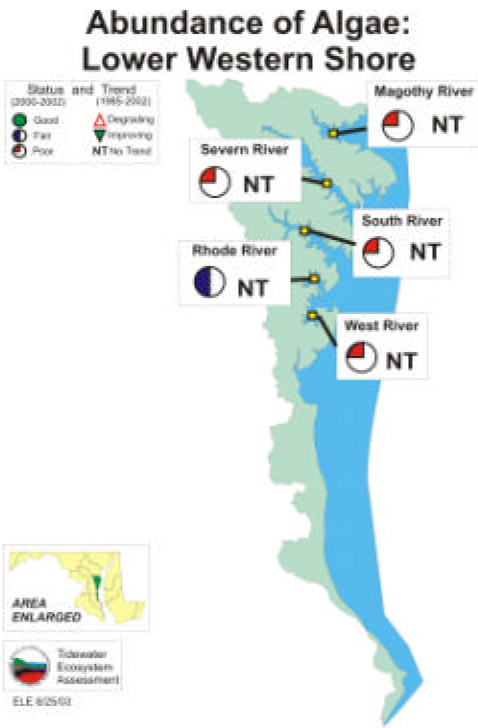


Figure LWS10 – Total Suspended Sediments in the Lower Western Shore

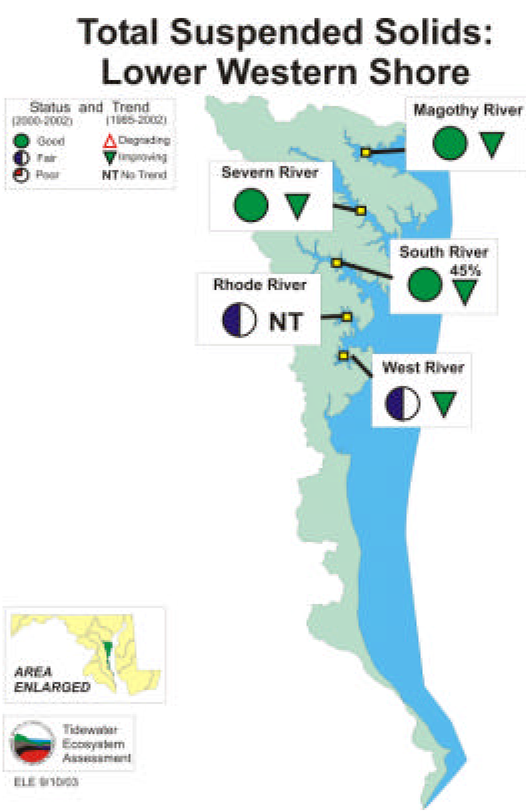


Figure LWS11 – Secchi Depth in the Lower Western Shore.

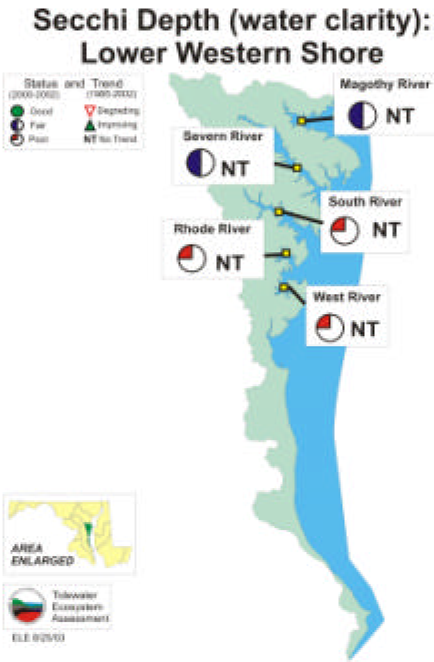
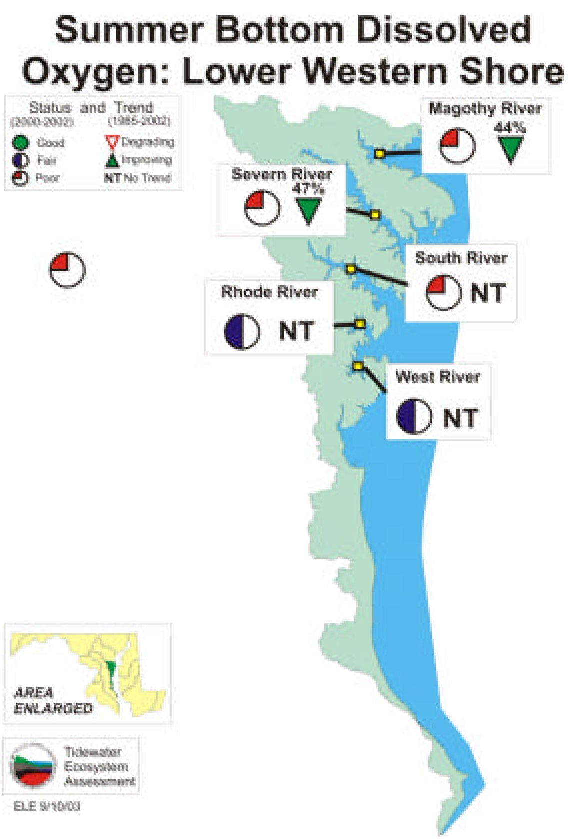


Figure LWS12 – Summer Dissolved Oxygen in the Lower Western Shore.



Overview of Monitoring Results

Water and Habitat Quality

Non-tidal Water Quality Monitoring Information Sources

Much useful information on non-tidal water quality is available on the Internet. The State of Maryland's Biological Stream Survey (MBSS) basin fact sheets and basin summaries are available at:
http://www.dnr.state.md.us/streams/mbss/mbss_fs_table.html
MBSS also reports stream quality information summarized by county at:
http://www.dnr.state.md.us/streams/mbss/county_pubs.html In addition to these reports and fact sheets, detailed and more recent information and data are also available on the MBSS website: **http://www.dnr.state.md.us/streams/mbss**

Information on Prince George's County water quality monitoring and stream assessments are available at:
http://www.co.pg.md.us/Government/AgencyIndex/DER/PPD/Environment_Protection/water_quality.asp?h=20&s=40&n=50&n1=150

Water quality information collected by Maryland's volunteer Stream Waders is available at: **http://www.dnr.state.md.us/streams/mbss/mbss_volun.html**

Long-term Water Quality Monitoring

Good water quality is essential to support the animals and plants that live or feed in the Lower Western Shore tributaries. Important water quality parameters are measured at five long-term tidal stations in the Lower Western Shore, including nutrients, water clarity (Secchi depth), dissolved oxygen, total suspended solids, and algal abundance.

Current status is determined based on the most recent three-year period (2000-2002). For dissolved oxygen, the current are compared to ecologically meaningful thresholds to assign a status of good, fair, or poor. Thresholds have not been established for the other parameters, so the current data are compared to a baseline data set, and assigned a status of good, fair, or poor, which is only a *relative* status compared to the baseline data. Trends are determined using a non-parametric test for trend (the Seasonal Kendall test). For a detailed description of the methods used to determine status and trends, see http://www.dnr.state.md.us/bay/tribstrat/status_trends_methods.html.

Although total nitrogen and total phosphorus generally decreased over the 1985 to 2002 period, algal levels remained poor and did not decrease. Total suspended solids levels are relatively fair to good and improving, but water clarity (Secchi depths) are relatively poor. Dissolved oxygen levels are poor at the Magothy, Severn, and South River stations and have worsened in the Magothy and the Severn.

SAV

The well-defined linkage between water quality and submerged aquatic vegetation (SAV) distribution and abundance make SAV communities good barometers of the health of estuarine ecosystems. SAV is important not only as an indicator of water quality, but it is also a critical nursery habitat for many estuarine species. Blue crab post-larvae are 30 times more abundant in SAV beds than adjacent unvegetated areas. Similarly, several species of waterfowl are dependant on SAV as food when they over-winter in the Chesapeake region.

The Chesapeake Bay Program has developed new criteria for determining SAV habitat suitability of an area based on water quality. The APercent Light at Leaf@ habitat requirement assesses the amount of available light reaching the leaf surface of SAV after being attenuated in the water column and by epiphytic growth on the leaves themselves. The document describing this new model is found on the Chesapeake Bay Program website (www.chesapeakebay.net/pubs/sav/index.html). The older AHabitat Requirements@ of five water quality parameters are still used for diagnostic purposes. Re-establishment of SAV is measured against the ATier 1 Goal@, an effort to restore SAV to any areas known to contain SAV from 1971 to 1990.

The Magothy River has shown an increasing trend in SAV coverage from 1993 to 1998 (www.vims.edu/bio/sav/), reaching 198 acres in 1998, or attaining 34% of the Tier I goal of 585 acres. 1999 witnessed a decline in SAV coverage to 65 acres (incomplete aerial photography for that year), rebounding to 90 acres in 2000 (Figure LWS13). No data were collected in 2001 due to flight restrictions following the terrorist attacks on New York and the Pentagon. Extensive ground-truthing by U. S. Fish and Wildlife Service has found 13 different species throughout the river, with horned pondweed, widgeon grass and milfoil the most common species found. Water quality data from the monitoring station located between North and South Ferry Points indicate that the SAV habitat requirements are met for suspended solids and phosphorous concentrations. Light attenuation, percent light at leaf, nitrogen and algae levels are borderline.

The Severn River has shown an increasing trend in SAV coverage (Figure LWS13), beginning in 1994 through 1999 (www.vims.edu/bio/sav/). The 1999 SAV coverage is the largest amount of SAV that has ever been recorded and was within 9 acres of attaining the Tier I goal of 464 acres. However, the 2000 acreage was down substantially, to128 acres, most likely due to massive algae blooms. Anecdotal accounts indicate that SAV recovered in 2001. However, VIMS was unable to get complete coverage, again due to flight restrictions. The beds are typically located downstream of Cedar Point, and upstream of Weems Creek, with the most SAV found in Round Bay. Ground-truthing by citizens and the U. S. Fish and Wildlife Service has found 5 species in Severn River, in the following order of occurrence: horned pondweed, widgeon grass, redhead grass, milfoil and sago pondweed. Data from the water quality monitoring site located near the U. S. Route 50 bridge indicate that the SAV habitat requirements are met for suspended solids, nitrogen and phosphorous concentrations. Light attenuation and percent light at leaf are borderline, while concentration of algae failed the habitat requirement.

The South River showed an increasing trend in SAV coverage (www.vims.edu/bio/sav/), beginning in 1994 and ending in 1998, where SAV coverage was 54 acres, exceeding the Tier I goal of 51 acres (Figure LWS13). SAV coverage was down to 17 acres in 1999 and no SAV was reported in 2000, again most likely due to algae blooms. In 2001 there were 27 acres of SAV (52% of Tier I). Most SAV beds have been located between Mayo and Larrimore Points, primarily on the southern shore. There has been extensive ground-truthing of this area by citizens, and they have identified 6 species, listed here in order of occurrence: horned pondweed, widgeon grass, slender pondweed, curly pondweed, wild celery and 1 un-identified species. Data from the water quality-monitoring site located near Shadow Point indicate that the SAV habitat requirements are met for suspended solids and nitrogen concentrations and borderline for phosphorous levels and percent light at leaf. The river fails for light attenuation and algae concentrations.

For the Rhode River, SAV has not been reported since 1978 by the aerial survey (www.vims.edu/bio/sav/), and this coverage represents the Tier I goal of 15 acres (Figure LWS13). Citizen ground-truthing has found four species of SAV, horned pondweed, widgeon grass, milfoil and an un-identified species, scatter throughout the river. Data from the water quality-monitoring site located near High Island indicate that the SAV habitat requirements are borderline for suspended solids, phosphorous and algae concentrations. Nitrogen levels pass, and the river fails for light attenuation and percent light at leaf.

The West River has had very little SAV mapped since 1984 (www.vims.edu/bio/sav/). There were approximately 10 acres in 1994 and 1998, well below the Tier I goal of 116 acres (Figure LWS13). The beds mapped in 1998 were located near Curtis Point. There has only been one spot ground-truthed in this river, in Johns Creek by a citizen in 1995, who found only widgeon grass. Data from the water quality-monitoring site located near Councillors Point indicate that the SAV habitat requirements are met only for phosphorous and nitrogen concentrations. Suspended solids and algae levels are borderline, and the river fails for light attenuation and percent light at leaf.

Figure LWS13 - Submerged Aquatic Vegetation in the Lower Western Shore.

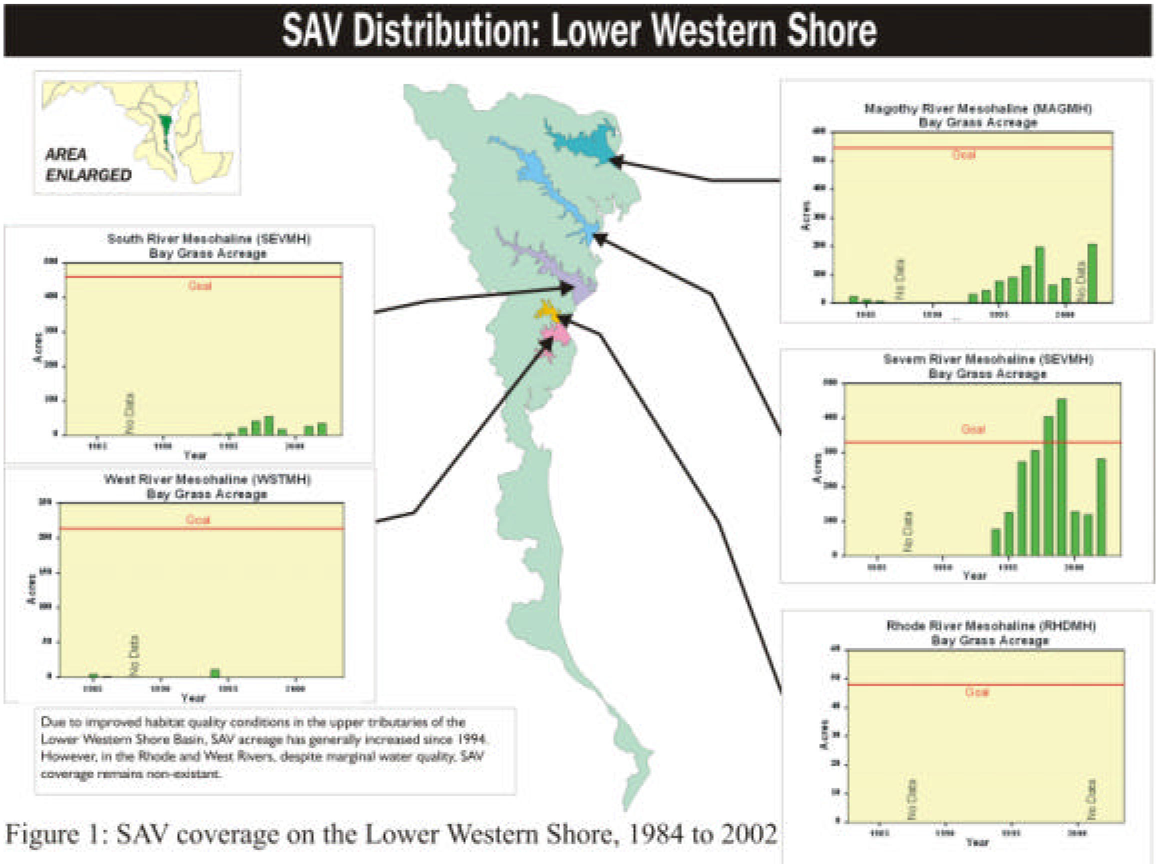


Figure 1: SAV coverage on the Lower Western Shore, 1984 to 2002

<u>Benthic Community</u>

The benthic community forms an integral part of the ecosystem in estuarine systems. For example, small worms and crustaceans are key food items for crabs and demersal fish, such as spot and croaker. Suspension feeders that live in the sediments, such as clams, can be extremely important in removing excess algae from the water column. Benthic macroinvertebrates are reliable and sensitive indicators of estuarine habitat quality.

Benthic monitoring includes both probability-based sampling (sampling sites are selected at random) and fixed station sampling (the same site is sampled every year). There are 54 random sites and one fixed site in the Lower Western Shore basin. A benthic index of biotic integrity (B-IBI) is determined for each site (based on abundance, species diversity, etc.). The B-IBI serves as a single-number indicator of benthic community health. For a more details on the methods used in the benthic monitoring program see http://esm.versar.com/Vcb/Benthos/backgrou.htm

From 1995 through 2000, benthic community condition in lower western shore basin tributaries was best in the South and West rivers and worst in the Magothy and Severn rivers (Figure LWS15). The Rhode River had a 50 percent probability of degraded benthos.

Figure LWS14. Trends in benthic community condition, 1985-2000. Trends were identified using the van Belle and Hughes (1984) procedure. Current mean B-IBI and condition are based on 1998-2000 values. Initial mean B-IBI and condition are based on 1995-1997 values. NS: not significant.

Station	Trend Significance	Median Slope (B-IBI units/yr)	Current Condition (1998-2000)	Initial Condition (1995-1997)
204	NS	0.00	3.70 (Meets Goal)	3.70 (Meets Goal)

Figure LWS15. Number of benthic sampling sites failing the B-IBI and probabilities (and SE) of observing degraded benthos, non-degraded benthos, or benthos of intermediate condition (indeterminate for low mesohaline habitats) for Lower Western Shore Basin segments, 1995-2000. Probabilities and standard errors were adjusted according to Agresti and Caffo (2000). Standard errors were used to calculate 67 percent (±SE) and 90 percent (±1.65 x SE) confidence limits. Adjusted probabilities do not add to 100 percent.

Segment	River	Number of Sites	Sites Failing	P Deg.		P Non-deg.		P Interm.	
MAGMH	Magothy	17	10	57.1	(10.8)	28.6	(9.9)	23.8	(9.3)
SEVMH	Severn	13	7	52.9	(12.1)	29.4	(11.1)	29.4	(11.1)
SOUMH	South	11	4	33.3	(12.2)	46.7	(12.9)	33.3	(12.2)
RHDMH	Rhode	6	3	50.0	(15.8)	40.0	(15.5)	30.0	(14.5)
WSTMH	West	7	2	36.4	(14.5)	45.5	(15.0)	36.4	(14.5)

Nutrient Limitation

Like all plants, phytoplankton need nitrogen, phosphorus, light, and suitable water temperatures to grow. If light is adequate and the water temperature is appropriate, phytoplankton will continue to grow as long as unlimited amounts of nutrients are available. If nutrients are not unlimited, then the ratio of nitrogen to phosphorus affects phytoplankton growth. (Phytoplankton generally use nitrogen and phosphorus at a ratio of 16:1, that is, 16 times as much nitrogen is needed as phosphorus.) If one of the nutrients is not available in the adequate quantity, phytoplankton growth is 'limited' by that nutrient. If both nutrients are available in enough excess (regardless of the relative proportion of them) that the phytoplankton can not use them all even when they are growing as fast as they can under the existing temperature and light conditions, then the system is 'nutrient saturated.'

Nitrogen limitation occurs when there is insufficient nitrogen, i.e., there is excess phosphorus. Nitrogen limitation often happens in the summer and fall after stormwater flows are lower (so less nitrogen is being added to the water) and some of the nitrogen has already been used up by phytoplankton growth during the spring. If an area is nitrogen limited, then adding nitrogen will increase phytoplankton growth.

Phosphorus limitation occurs when there is insufficient phosphorus, i.e. there is excess nitrogen. If an area is phosphorus limited, then adding phosphorus will increase phytoplankton growth. Phosphorus limitation occurs in some locations in the spring when large amounts of nitrogen are added to the estuary from stormwater flow.

If an area is light limited, then both nitrogen and phosphorus are available in excess and a situation of nutrient saturation occurs. In this case, if phytoplankton are exposed to appropriate water temperatures and sufficient light, they will grow. If an area is both nitrogen and phosphorus limited, then both nitrogen and phosphorus must be added to increase algal growth.

Managers can use the nutrient limitation model to predict which nutrient is limiting at a given location and use the information to assess what management approach might be the most effective for controlling excess phytoplankton growth. If an area is phosphorus limited, then reducing phosphorus will bring the most immediate reductions in phytoplankton grown. However, if nitrogen levels are not also reduced, the excess nitrogen that goes unused can be exported downstream. This excess nitrogen may reach an area that is nitrogen limited, fueling phytoplankton growth in that downstream area. The nutrient limitation predictions are a valuable tool, but they must be used in conjunction with other water quality and watershed information to fully assess and evaluate the best management approach.

The nutrient limitation models were used to predict nutrient limitation for the five stations in the Lower Western Shore. Results are summarized for the most recent three-year period (2000-2002) by season: winter (December-February), spring (March-May), summer (July-September) and fall (October-November). Managers can use these predictions to assess what management approach will be the most effective for controlling excess phytoplankton growth. Interpreting the results can be a little counter-intuitive, however. Remember that nitrogen limited means that phosphorus is in excess. Initially, it would seem that the best management strategy would be to reduce phosphorus inputs. However, it may actually be more cost effective to further reduce nitrogen inputs to increase the amount of 'unbalance' in the relative proportions of nutrients so that phytoplankton growth is even more limited. When used along with other information available from the water quality and watershed management programs, these predictions will allow managers to make more cost-effective management decisions. See Appendix B for details.

Magothy River

Benthic Community

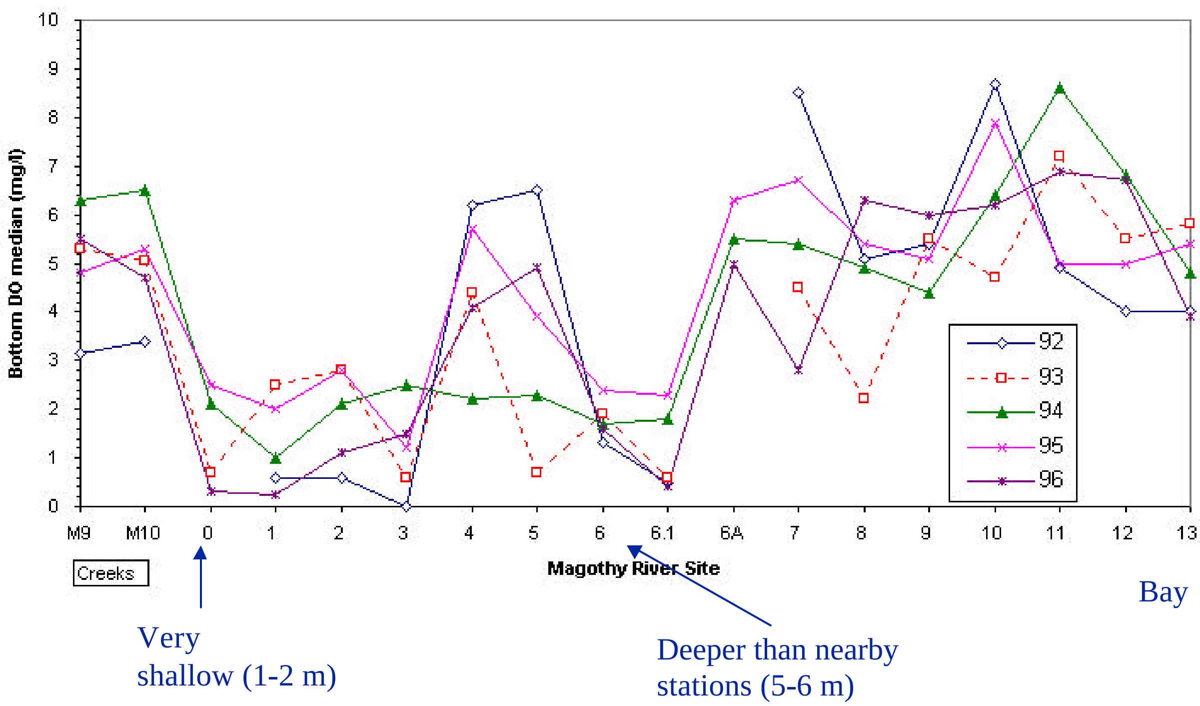
Sites with failing B-IBI in the Magothy River were located throughout the estuary, but were particularly concentrated in the upper southern shore. Eight sites were severely degraded and two sites were moderately degraded. Three of the severely degraded sites were associated with very low dissolved oxygen conditions (<0.7 mg/l) at time of sampling, but not all failing sites could be attributed to low dissolved oxygen. Two sites exhibited very high abundance with low biomass of pollution-sensitive organisms, suggesting that, in addition to low dissolved oxygen, other water quality factors such as the observed high nutrient and chlorophyll concentrations or the poor water clarity (low Secchi depths) may contribute to poor benthic condition.

Magothy River Association Water Quality Data

Between 1992 and 1996, the Magothy River Association collected water quality samples from 17 stations throughout the Magothy River. These data provide insight into the spatial trends in water quality. Of particular interest are spatial trends observed for dissolved oxygen and dissolved inorganic nitrogen concentrations.

Figure LWS17 illustrates spatial variability in dissolved oxygen. The highest dissolved oxygen concentrations were observed near the mouth of the River. Dissolved oxygen concentrations in the Magothy were lowest at several shallow, upstream stations, as well in the deep water near the Maryland DNR's Magothy River station. Historical data collected by the Chesapeake Bay Institute in 1958 also recorded anoxia and hypoxia in the Magothy's upstream areas.

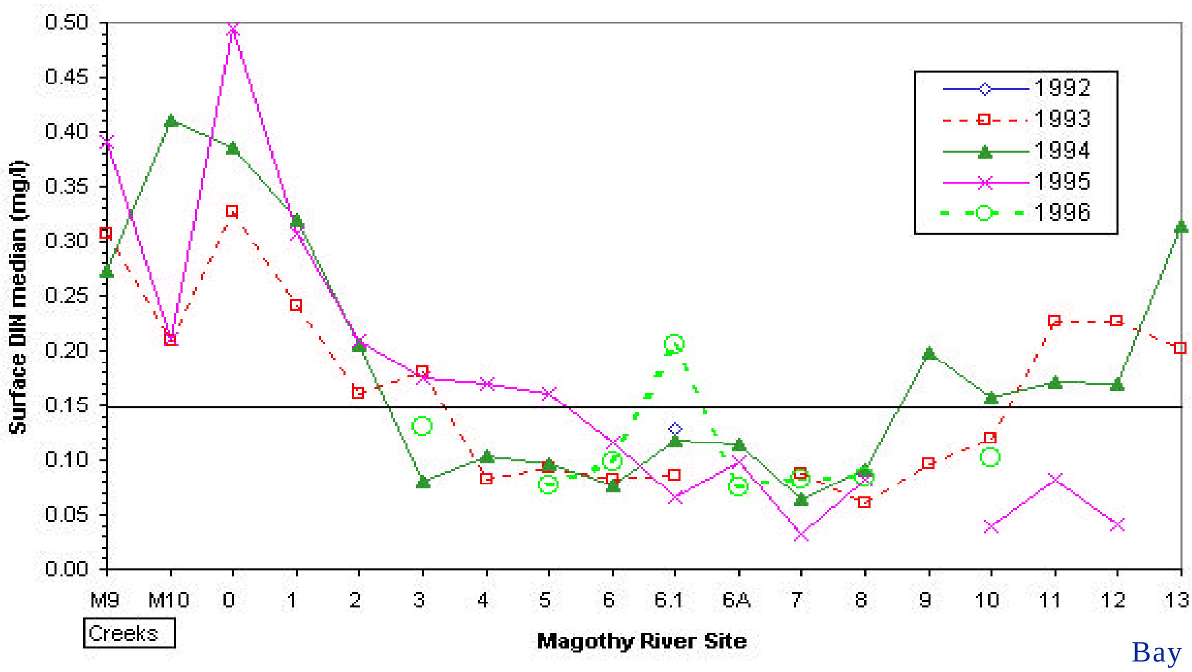
Figure LWS17 – Spatial Variability in Magothy River Dissolved Oxygen



Concentrations

Figure LWS18 illustrates spatial trends in dissolved inorganic nitrogen concentrations. Dissolved inorganic nitrogen concentrations in the Magothy were high both upstream and near the mouth. High dissolved inorganic nitrogen levels upstream are likely due to proximity to sources and less dilution from the river. Elevated dissolved inorganic nitrogen levels near the mouth of the river may be due to the influence of the Susquehanna River or outfalls from nearby wastewater treatment facilities.

Figure LWS18 – Spatial Variability in Magothy River DIN Concentrations



Severn River

Benthic Community

All sites with degraded benthos in the Severn River were located in the upper portion of the estuary, above the long-term water quality monitoring station (WT7.1). Although the water quality at station WT7.1 indicates fair dissolved oxygen status, all failing benthic samples but one in the upper Severn were azoic or nearly azoic (1 species), with dissolved oxygen readings at the time of sampling of less than 1.1 mg/l. In addition to the randomly located sites, a fixed long-term benthic monitoring station (#204) is also located mid-estuary in the Severn River. This location exhibits good benthic community condition with no significant trend (Table 2), suggesting that benthic degradation is limited to the upper portion of the estuary, where severe hypoxia or anoxia appears to be a problem.

South River

Benthic Community

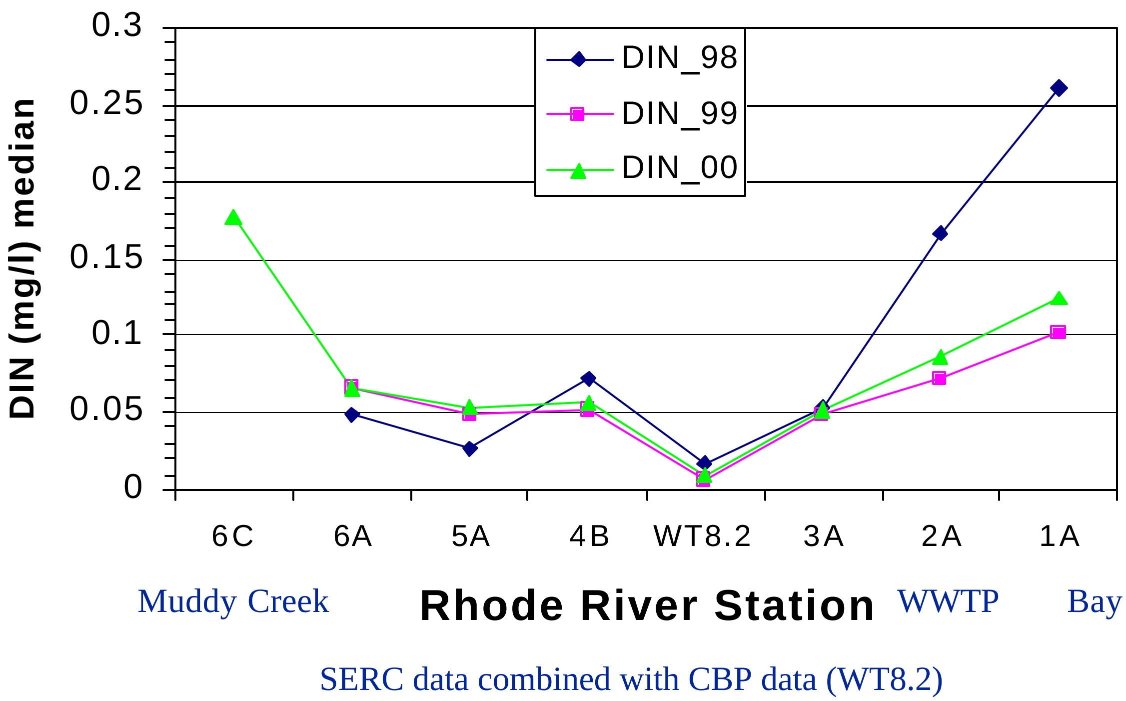
The South River had overall good benthic condition with failing sites only moderately degraded. Patterns of degradation could not be linked to low dissolved oxygen. The majority of sampling sites in the South River were concentrated in the lower half of the estuary, where hypoxia did not appear to be a problem. The long-term water quality monitoring station is located in the upper half of the estuary where average summer bottom dissolved oxygen levels are below 2 mg/L (status is poor).

Rhode River

Smithsonian Environmental Research Center (SERC) Water Quality Data

Between 1998 and 2000, researchers at SERC collected water quality data from seven stations in the Rhode River. These data provide insight into spatial variability in water quality parameters throughout the river system. Dissolved inorganic nitrogen measurements from the Rhode River reflect a similar pattern to that observed in the Magothy River. Dissolved inorganic nitrogen concentrations are high upriver, lower in the middle portions of the river, and then increase again near the mouth of the river. Upriver concentrations are likely high due to proximity to sources. Concentrations near the mouth may be higher due to nearby wastewater treatment plants or the influence of the Susquehanna River.

Figure LWS19 – Spatial Variability in Rhode River DIN Concentrations



Benthic Community

Half of the sampling sites in the Rhode River were severely degraded with low biomass and a high percentage of pollution-tolerant organisms. Benthic condition in the Rhode River could not be linked to low dissolved oxygen.

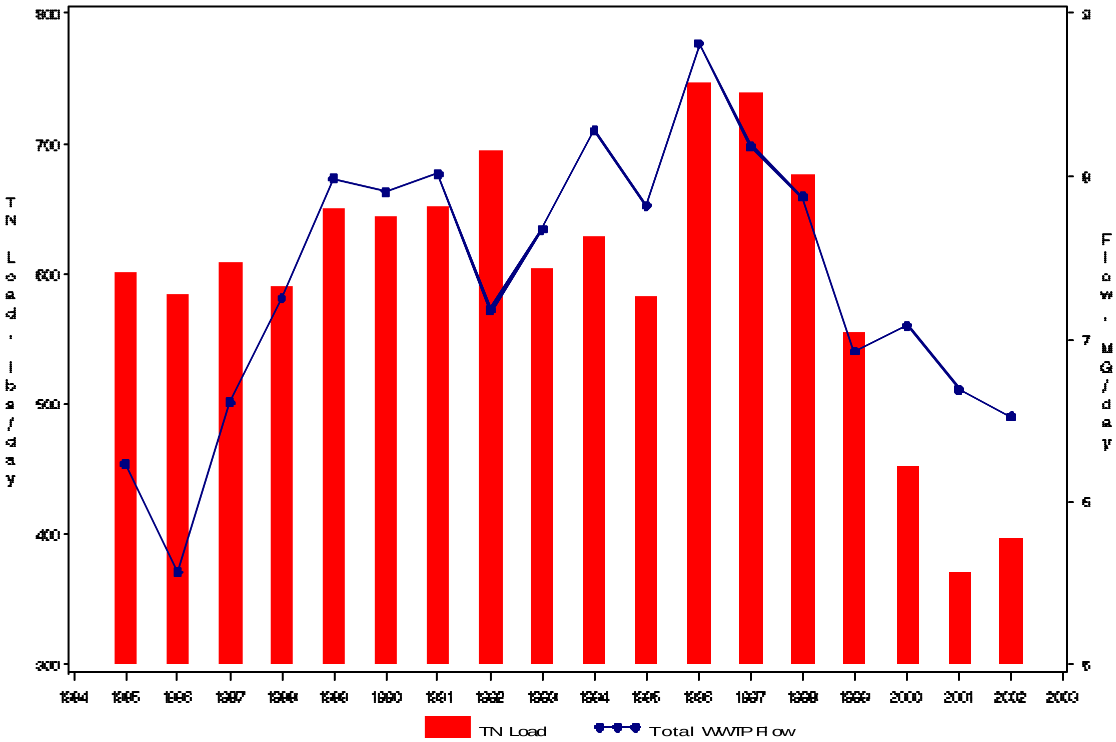
West River

Benthic Community

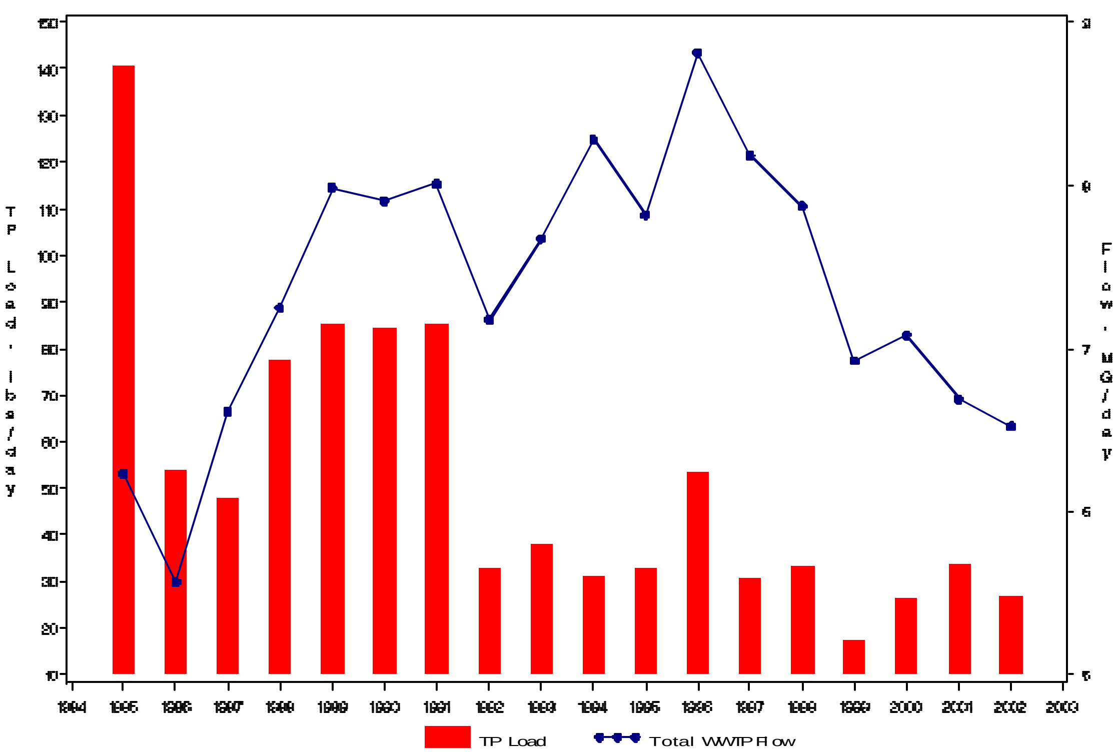
The River had overall good benthic condition with failing sites only moderately degraded. Patterns of degradation could not be linked to low dissolved oxygen.

Appendix A – Nutrient Loadings from Major Wastewater Treatment Facilities in the Lower Western Shore Basin

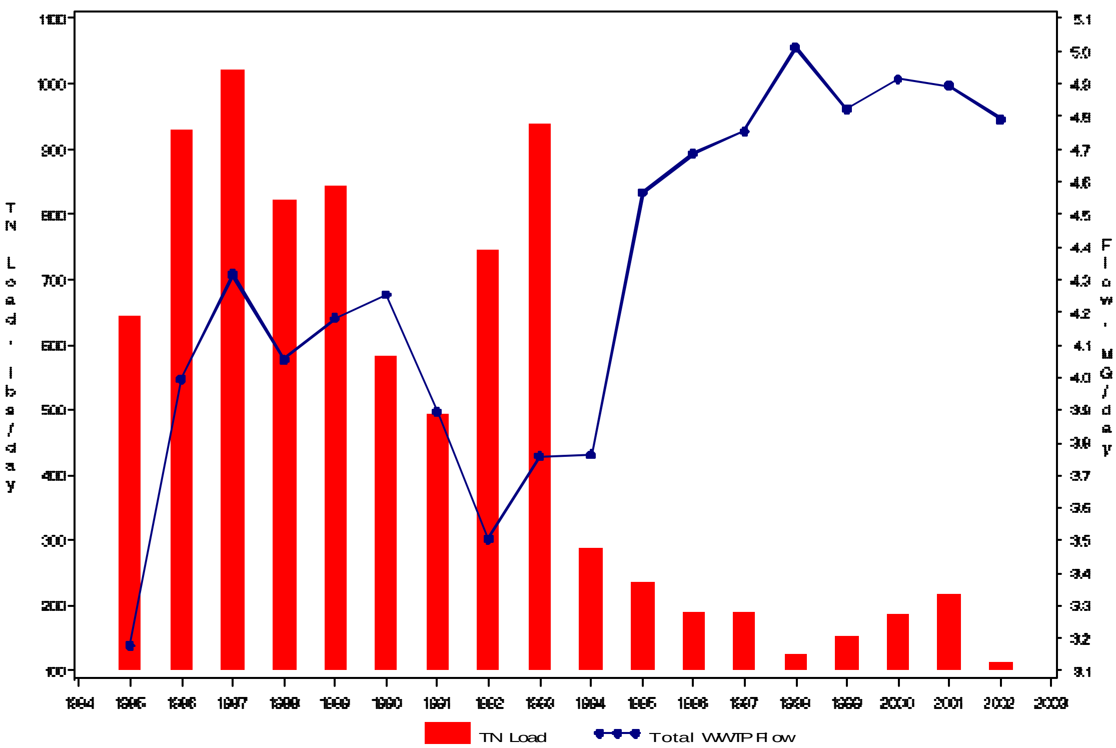
ANNAPOLIS Wastewater Treatment Plant: Lower Western Shore Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Flow



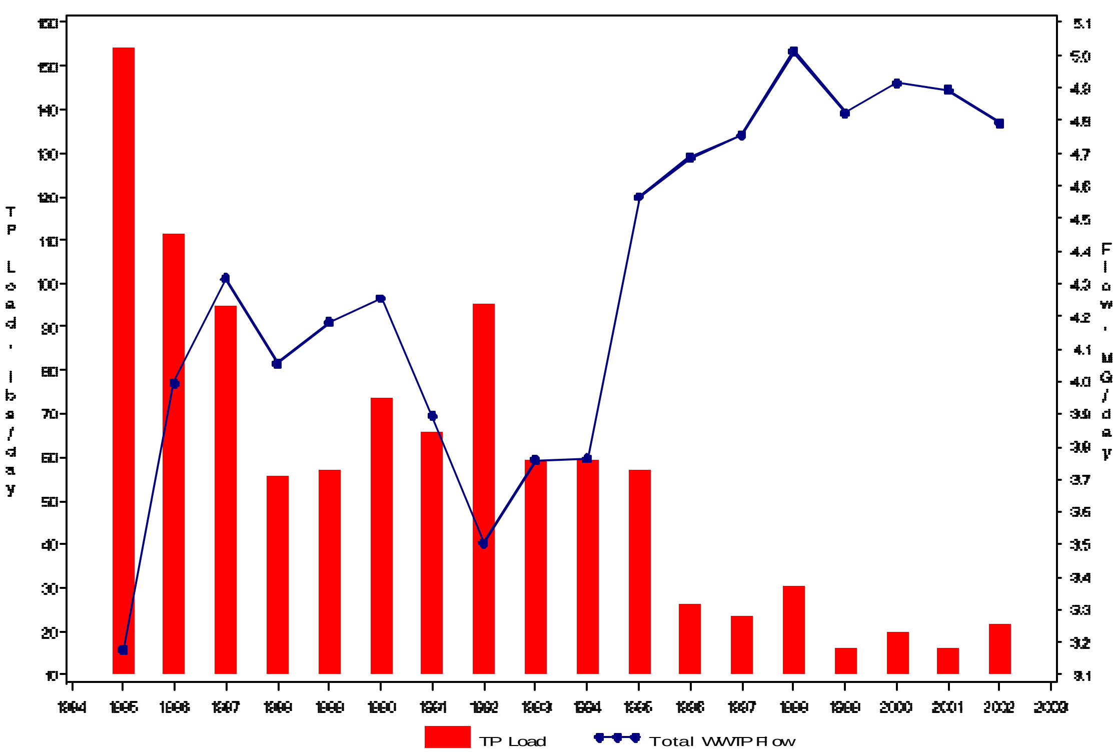
ANNAPOLIS Wastewater Treatment Plant: Lower Western Shore Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Flow



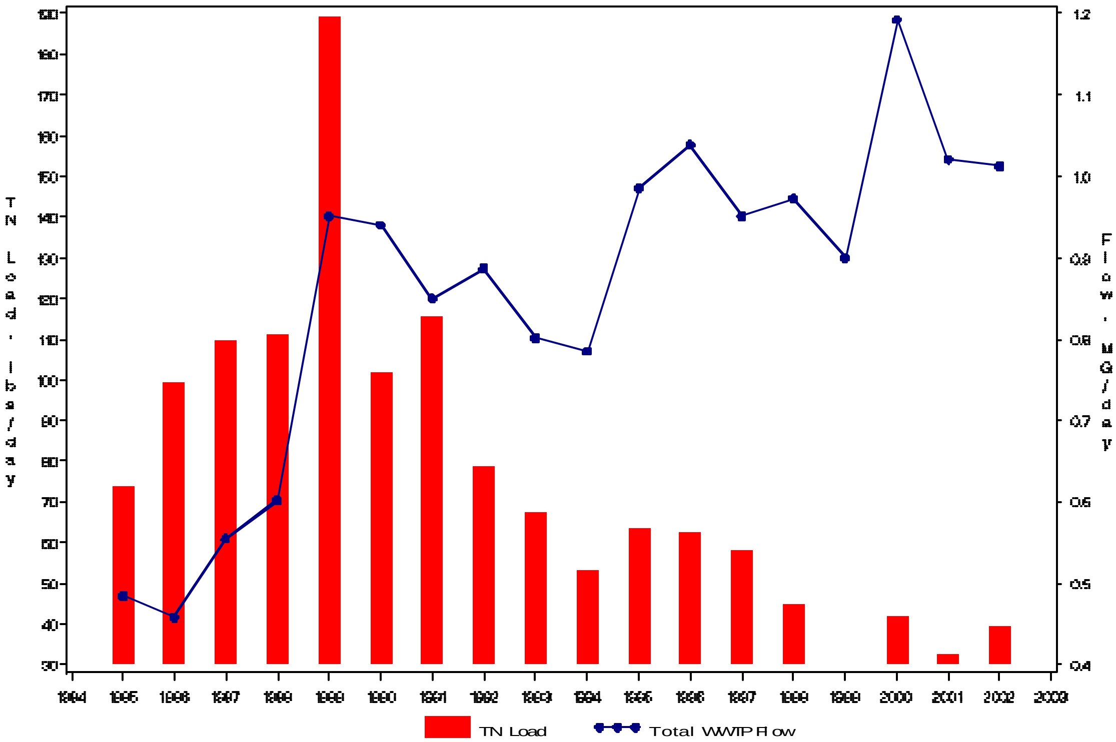
BROADNECK Wastewater Treatment Plant: Lower Western Shore Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Flow



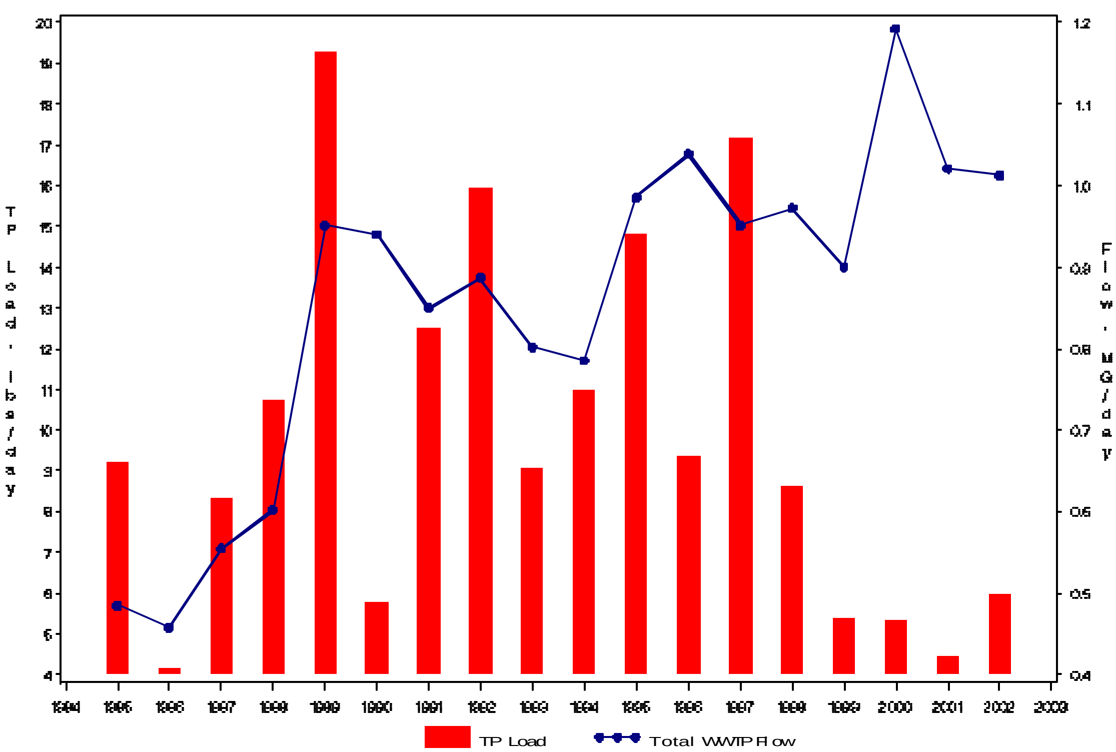
BROADNECK Wastewater Treatment Plant: Lower Western Shore Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Flow



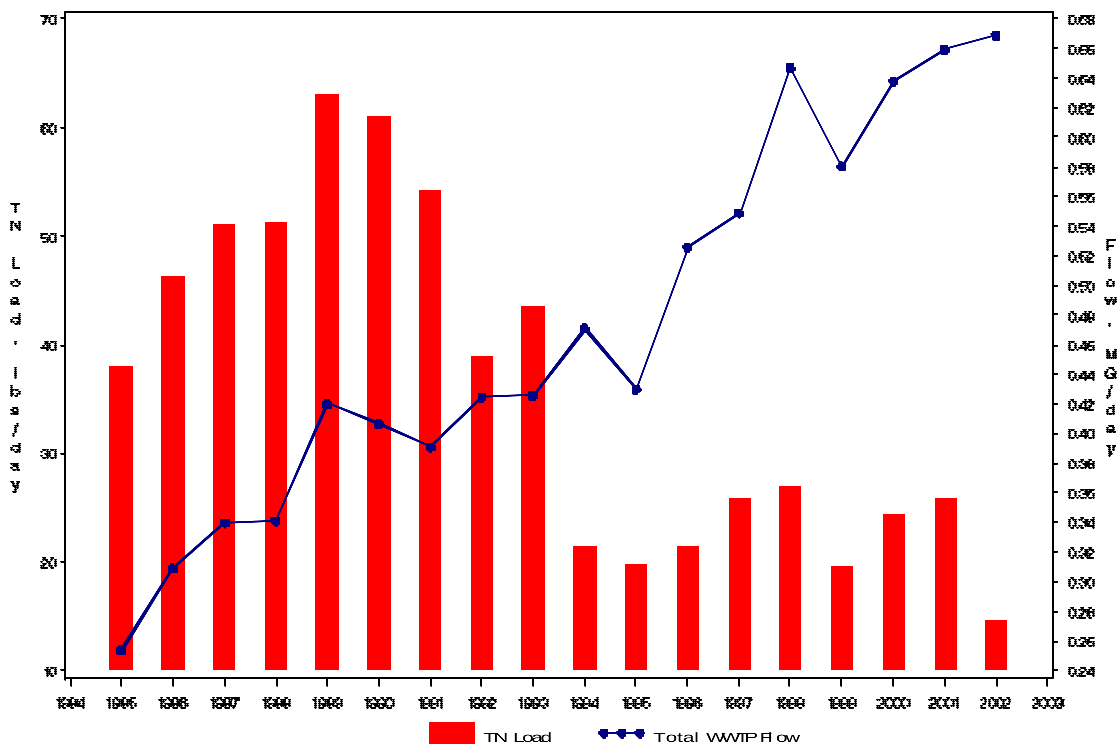
BROADWATER Wastewater Treatment Plant: Lower Western Shore Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Flow



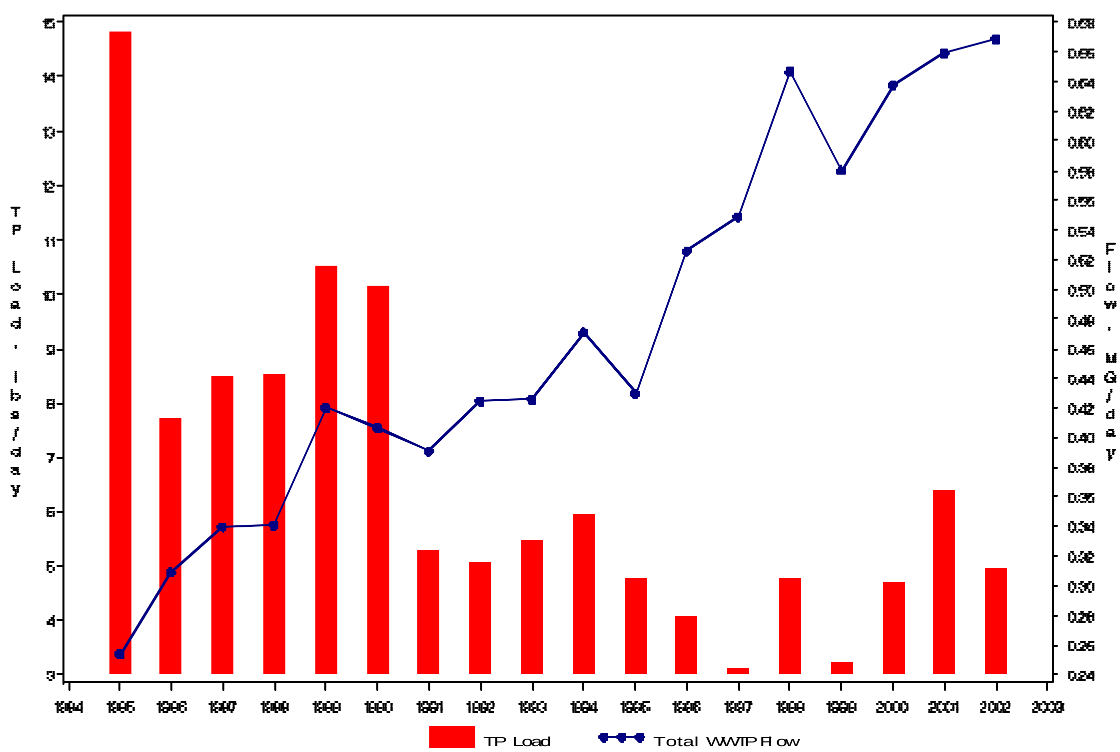
BROADWATER Wastewater Treatment Plant: Lower Western Shore Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Flow



CHESAPEAKE BEACH Wastewater Treatment Plant: Lower Western Shore Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Flow



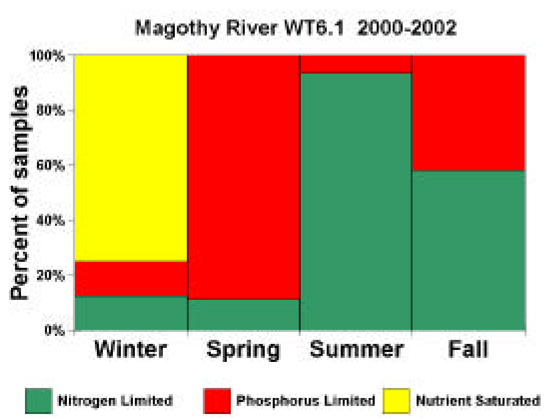
CHESAPEAKE BEACH Wastewater Treatment Plant: Lower Western Shore Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Flow

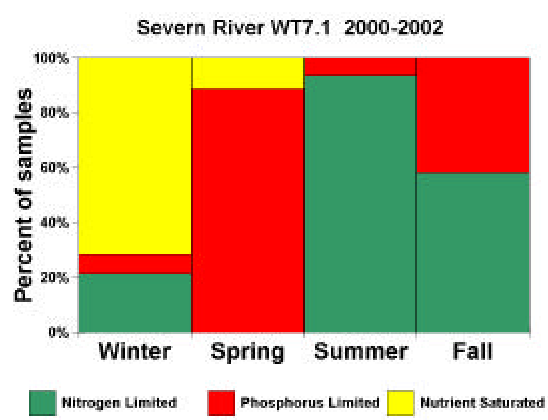


Appendix B – Nutrient Limitation Graphs for the Lower Western Shore Basin

The nutrient limitation models were used to predict nutrient limitation for the five stations in the Lower Western Shore. Results are summarized for the most recent three-year period (2000-2002) by season: winter (December-February), spring (March-May), summer (July-September) and fall (October-November). Managers can use these predictions to assess what management approach will be the most effective for controlling excess phytoplankton growth. Interpreting the results can be a little counter-intuitive, however. Remember that nitrogen limited means that phosphorus is in excess. Initially, it would seem that the best management strategy would be to reduce phosphorus inputs. However, it may actually be more cost effective to further reduce nitrogen inputs to increase the amount of 'unbalance' in the relative proportions of nutrients so that phytoplankton growth is even more limited. When used along with other information available from the water quality and watershed management programs, these predictions will allow managers to make more cost-effective management decisions.

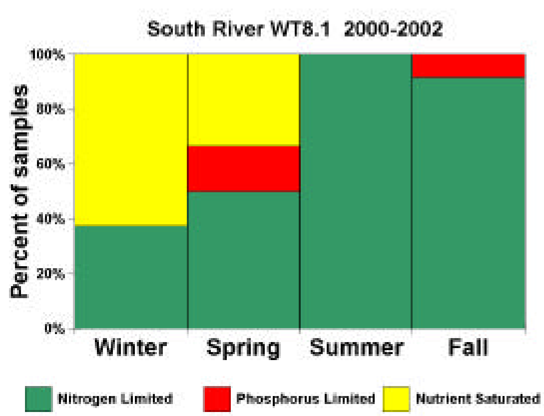
Magothy River (WT6.1) - On an annual basis, phytoplankton growth is nitrogen limited and phosphorus limited about 40% of the time each. In the winter, phytoplankton growth is nutrient saturated (light limited or no limitation) 75% of the time and nitrogen and phosphorus limited more than 10% of the time each. In the spring, growth is phosphorus limited about 90% of the time and nitrogen limited about 10% of the time. In the summer, phytoplankton growth is nitrogen limited almost 95% of the time and otherwise is phosphorus limited. In the fall, growth is nitrogen limited almost 60% of the time and phosphorus limited 40% of the time. Total nitrogen and total phosphorus concentrations are relatively fair and dissolved inorganic nitrogen and dissolved inorganic phosphorus concentrations are relatively good. Total nitrogen, dissolved inorganic nitrogen and total phosphorus concentrations are all improving (decreasing). The ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus is decreasing. Continued reductions in nitrogen would further limit phytoplankton growth at this station, while continued reductions in phosphorus will help bring the system into better balance, particularly in the winter and spring.

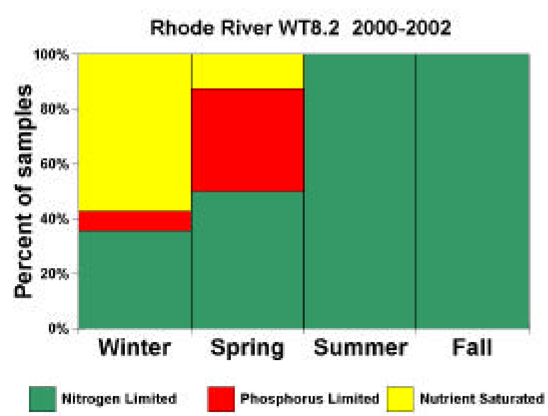




Severn River (WT7.1) - On an annual basis, phytoplankton growth is nitrogen limited and phosphorus limited about 40% of the time each. In the winter, phytoplankton growth is nutrient saturated (light limited or no limitation) about 70% of the time, nitrogen limited more than 20% of the time and phosphorus limited more than 5% of the time. In the spring, growth is phosphorus limited about 90% of the time and nutrient saturated about 10% of the time. In the summer, phytoplankton growth is nitrogen limited almost 95% of the time and otherwise is phosphorus limited. In the fall, growth is nitrogen limited almost 60% of the time and phosphorus limited 40% of the time. Total nitrogen concentration is relatively fair and total phosphorus, dissolved inorganic nitrogen and dissolved inorganic phosphorus concentrations are relatively good. Total nitrogen, dissolved inorganic nitrogen and total phosphorus concentrations are all improving (decreasing). The ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus ratio is relatively high in the spring, indicating that reductions in phosphorus would reduce spring phytoplankton growth; this ratio is relatively low in the summer and fall, indicating additional reductions in nitrogen concentrations will further limit phytoplankton growth during these seasons.

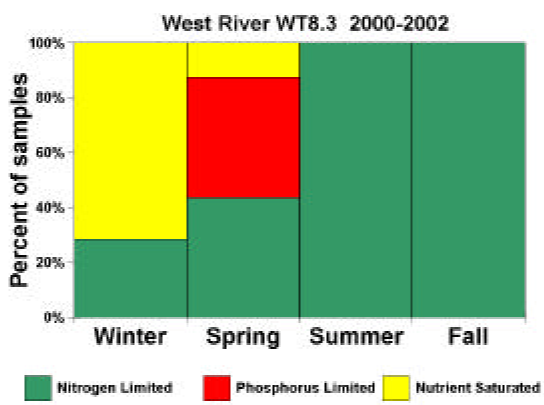
South River (WT8.1) - On an annual basis, phytoplankton growth is nitrogen limited 70% of the time and nutrient saturated (light limited or no limitation) 25% of the time. In the winter, phytoplankton growth is nitrogen limited almost 40% of the time and is otherwise nutrient saturated. In the spring, phytoplankton growth is nitrogen limited 50% of the time and phosphorus limited more than 15% of the time. In the summer phytoplankton growth is nitrogen limited. In the fall, growth is nitrogen limited more than 90% of the time and otherwise is phosphorus limited. Total nitrogen, total phosphorus and dissolved inorganic phosphorus concentrations are relatively fair and dissolved inorganic nitrogen concentration is relatively good. Dissolved inorganic nitrogen and total phosphorus concentrations are improving (decreasing). The ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus ratio is decreasing; this ratio is relatively low in all seasons, indicating that continued reductions in nitrogen would further limit algal production. Continued reductions in phosphorus would help bring the system into better balance.





Rhode River (WT8.2) - On an annual basis, phytoplankton growth is nitrogen limited 70% of the time and is nutrient saturated (light limited or no limitation) 15% of the time. In winter, phytoplankton growth is nitrogen limited about 35% of the time, phosphorus limited more than 5% of the time, and nutrient saturated almost 60% of the time. In spring, growth is nitrogen limited 50% of the time and phosphorus limited more than 35% of the time. In the summer and fall, phytoplankton growth is entirely nitrogen limited. Total nitrogen, total phosphorus and dissolved inorganic phosphorus concentrations are relatively fair and dissolved inorganic nitrogen concentration is relatively good. Dissolved inorganic nitrogen and total phosphorus concentrations are improving (decreasing). The ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus is relatively low in all seasons, indicating that continued reductions in nitrogen would further limit algal production. Continued reductions in phosphorus would help bring the system into better balance.

West River (WT8.3) - On an annual basis, phytoplankton growth is nitrogen limited more than 65% of the time. In the winter, phytoplankton growth is nitrogen limited about 30% of the time and is otherwise nutrient saturated (light limited or no limitation). In spring, growth is nitrogen limited almost 45% of the time and phosphorus limited almost 45% of the time. In the summer and fall, phytoplankton growth is entirely nitrogen limited. Total nitrogen and total phosphorus concentrations are relatively fair and dissolved inorganic nitrogen and dissolved inorganic phosphorus concentrations are relatively good. Total phosphorus concentration is improving (decreasing). The ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus is relatively low throughout the year, indicating that continued reductions in phosphorus concentrations in addition to reductions in nitrogen might further reduce phytoplankton growth and bring the system into better balance.



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